Radar Measurement of Waves and Currents in the Nearshore Zone

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LONG-TERM GOALS

Our long-term goal is to contribute to our understanding of processes in the upper ocean and lower atmosphere through the development and application of novel microwave, acoustic, and optical remote sensing techniques.

OBJECTIVES

The objectives of this effort are (1) to analyze radar data collected during NCEX and related deployments to determine how Doppler radar techniques can provide useful estimates of nearshore currents within and beyond the surf zone, and (2) to develop and apply Doppler radar techniques to large area surface wave and current mapping in the nearshore environment.

APPROACH

Our approach has been to analyze data collected from both the deployment of the FOPAIR radar system at the Scripps Institute of Oceanography in 2000, and from the 2003 deployment of two microwave marine radar systems in the Nearshore Canyon Experiment (NCEX). The FOPAIR system was deployed specifically to capture high resolution backscatter from the surf zone and nearshore incident wave field in an area instrumented with in situ velocity and pressure sensors. The modified marine radars systems were deployed during NCEX to provide synoptic images of the incident wave fields and surface currents through measurement of backscattered power and Doppler velocities. We have analyzed the FOPAIR data collected in 2000 to further our understanding of backscatter from nearshore breaking waves and inter-bore processes (*Farquharson et al.*, 2005), and to aid in interpreting the measurements made during NCEX. We are now in the process of comparing NCEX radar measurements with other remote sensing techniques (namely, video) and in situ measurements to identify scattering mechanisms observed during the experiment.

WORK COMPLETED

Work has progressed along two fronts: analysis of radar observations and development of improved radar instrumentation. The analysis of radar observations has focused on studying the relationship between microwave imaging radar measurements of fluid velocities in the surf zone, and shoaling, breaking, and

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14. ABSTRACT
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15. SUBJECT TERMS

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broken waves observed with in situ instrumentation. We have estimated normalized radar cross section (NRCS) and Doppler velocity from measurements at near-grazing angles, and compared these with in situ fluid velocities measured with acoustic Doppler velocimeters (ADVs). A journal manuscript was completed and accepted for publication.

We are progressing in our efforts to compare radar measurements with video observations to identify features observed by the radar during NCEX. Radar and merged video images from two NRL video cameras have been rectified to the Argus coordinate system for comparison. Thus far, comparisons suggest that microwave radar is sensitive to low-grazing angle scattering from foam patches under the low wind speed conditions encountered during much of NCEX. We have also provided radar images to the Naval Postgraduate School (E. Thornton) to aid in their study of the longshore length scale of energy groups in the nearshore. These efforts were performed by graduate student, Gordon Farquharson, who defended his Ph.D. dissertation in Nov 2004 and is currently employed by NCAR in Boulder, CO.

We are also investigating the retrieval of bathymetric profiles from NCEX radar backscatter images through analysis of the gravity wave dispersion. Radar data used in this analysis was collected when wind was sufficient to produce a visible incident wave field in radar backscatter images. If successful, this should result in retrieval of two dimensional maps of bathymetric data that can be comapred with surveyed depths.

Finally, we are constructing a solid-state version of the marine Doppler radar. Unlike the radars deployed during NCEX that use high-power (25 kW magnetron tube) transmitters, this will employ a low-power (10 W) semiconductor-based transmitter. Frequency modulation and pulse compression will be employed to yield improved spatial resolution and Doppler frequency stability. The new system will be tested in spring 2006 from a location either on Cape Cod or Cape Ann. These latter efforts are being performed by graduate students Dragana Perkovic and Gita Pathak.

RESULTS

Analysis of nearshore scattering recorded by FOPAIR shows that joint histograms of radar cross section and Doppler velocity cluster into distinct distributions. One distribution is characterized by large NRCS and high Doppler velocity ($>$ 2 m/s). Such echoes are observed to decrease in amplitude with decreasing bore height as they progress to the shoreline. The NRCS is reasonably well modelled by scattering from a cylinder with radius equal to the bore height (Figure 1). Also, the Doppler velocities associated with these regions in the joint histograms agree well with theoretical wave phase velocities (Figure 2). As a result, it is possible to use these radar echoes to estimate both bore height and phase velocity with cross-shore location within the surf zone.

Instantaneous inter-bore Doppler velocities are correlated with ADV measured fluid velocities, but are offset by 0.8 m/s (Figure 3). Our analysis suggests that this offset is due primarilty to differences in the mean flows at the surface observable by radar and subsurface flows observable by ADVs. In addition, other influences may include Bragg-resonant capillary wave phase velocities, wind drift, and the finite spatial resolution of the radar, though these other influences, taken together, cannot explain all the observed difference in the mean velocities.

Radar and video images recorded during NCEX are shown in Figures 4(a) and 4(b). “Patches” of

backscatter in the radar image are less distinct due to wind-generated surface roughness. However, in areas of increased backscatter, the video images do show streaks and patches of foam. The streaks of foam are narrow bands of approximately 5 meters width. Interestingly, there is not a strong correlation between the specific shapes of the foam streaks from video and the features evident in the radar images. However, regions containing foam in the video are correlated with regions of higher backscattered power from the radar. Thus, we expect that some surface roughness not visible in the video is contributing to the radar signature. Figure 4(c) shows the surface vector field computed with the feature-tracking algorithm from data shown in Figure 4(a). Surf zone vectors have been removed from the figure as estimates in this region are contaminated by bore phase velocities. An offshore directed flow which could be the surface signature of a rip current is evident between $y = -800$ and -1000 and seaward of the surf zone. This region corresponds to the large patch of backscatter shown in Figure 4(a), and also with foam visible in the video image. While these results are encouraging, we need to find better comparison cases, and plan to conduct a more rigorous cross-correlation analysis.

IMPACT/APPLICATIONS

The work presented describes the first detailed analysis and interpretation of radar backscatter in the nearshore region with detailed in-situ using verification. These results will aid in interpretation of microwave radar measurements made during NCEX. Furthermore, the observations made during NCEX may be the first of low-grazing scattering from foam, and if validated, will extend the observation capabilities of microwave radar in the nearshore by allowing us to develop new techniques for observing nearshore dynamics with microwave radar under low wind conditions.

TRANSITIONS

None

RELATED PROJECTS

Dual-Beam Interferometer Development and Validation (N00014-98-1-0612). Results from this project to develop an airborne technique for coastal current mapping via synthetic aperture radar have been accepted for publication *(Toporkov et al., 2005)*. Figure 5 shows tidal flow observed with the SAR through an inlet on the FL Gulf coast. Estimated velocity vectors are overlaid on the radar images. These research flights of the UMass DBI-SAR were performed in collaboration with NRL.

PUBLICATIONS

Farquharson, G., 2004. “Microwave Radar Observations of Nearshore Ocean Dynamics”, Ph.D. Dissertation, University of Massachusetts, Amherst, MA.

Farquharson, G., S.J. Frasier, B. Raubenheimer, and S. Elgar, 2005. “Microwave Radar Cross Sections and Doppler Velocities Measured from the Surf Zone”, *J. Geophys. Res.*, to appear, doi:10.1029/-2005JC003022.

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Farquharson, G., S.J. Frasier, B. Raubenheimer, and S. Elgar, 2005. “Microwave Radar Cross Sections and Doppler Velocities Measured from the Surf Zone”, *Accepted for publication*, doi:10.1029/-2005JC003022.

Puleo, J.A., G. Farquharson, S.J. Frasier, and K.T. Holland, 2003. “Comparison of optical and radar measurements of surf and swash zone velocity fields”, *J. Geophys. Res.*, **108**(C3), 3100, doi:10.1029/2002JC001483.

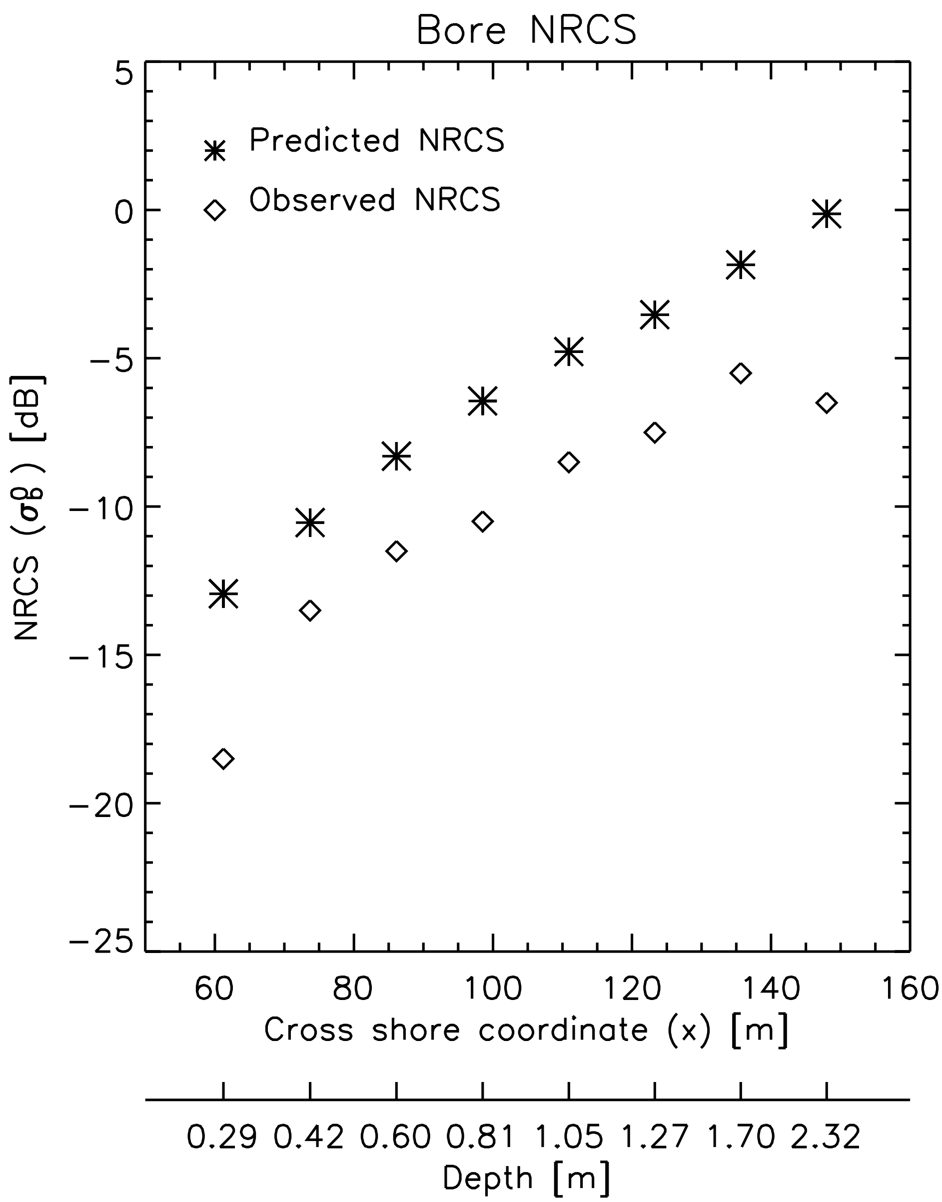


Figure 1: Predicted (asterisks) and observed (diamonds) NRCS values versus cross-shore coordinate (and associated depth). Predicted values are based on a scattering from a cylinder of radius equal to measured bore height. Corresponding inter-bore NRCS values are -32 ±2 dB.

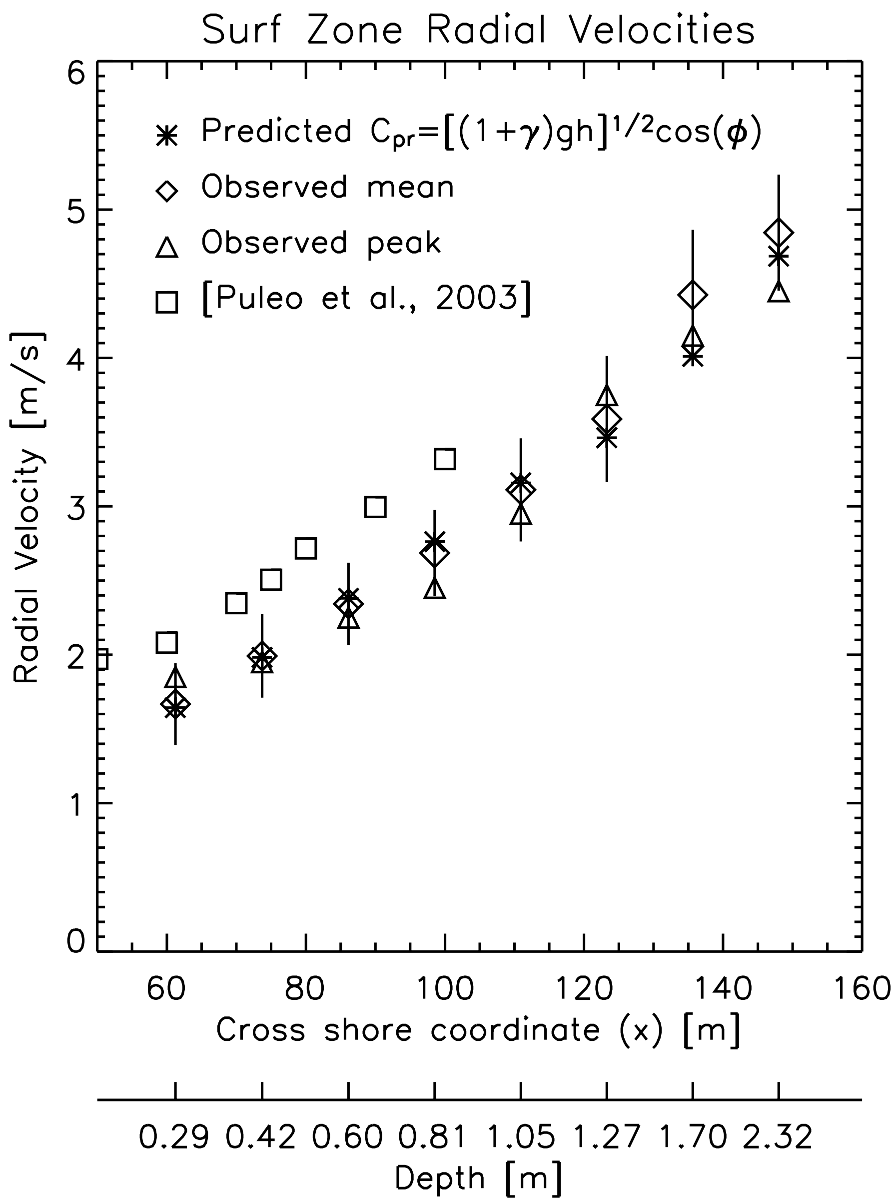


Figure 2: Radial velocity versus cross-shore coordinate (and depth). Asterisks are theoretically predicted shallow-water phase velocities, diamonds are observed radial velocities corresponding to the means of the joint histograms for radar azimuths from $-2.49°$ to $+2.49°$, triangles are the observed radial velocities corresponding to the peaks of the histograms, and squares are the observed radial velocities corresponding to pixels with the largest NRCS values (from [*Puleo*, 2003]). The rms difference between the observations (diamonds) and the predictions (asterisks) is 0.17 m/s.

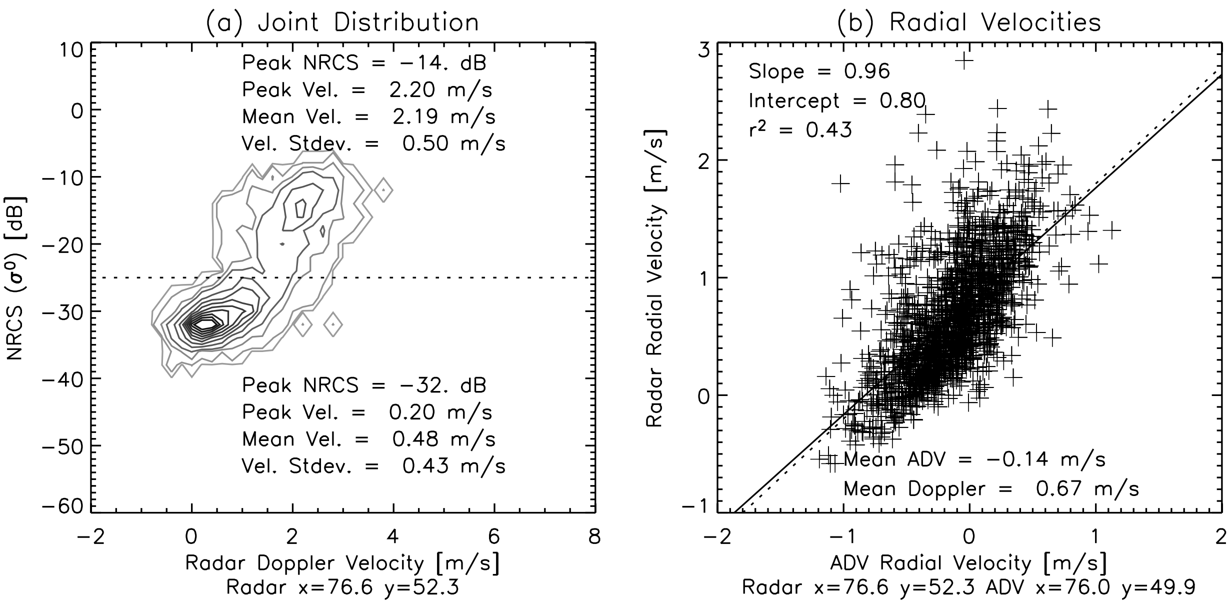
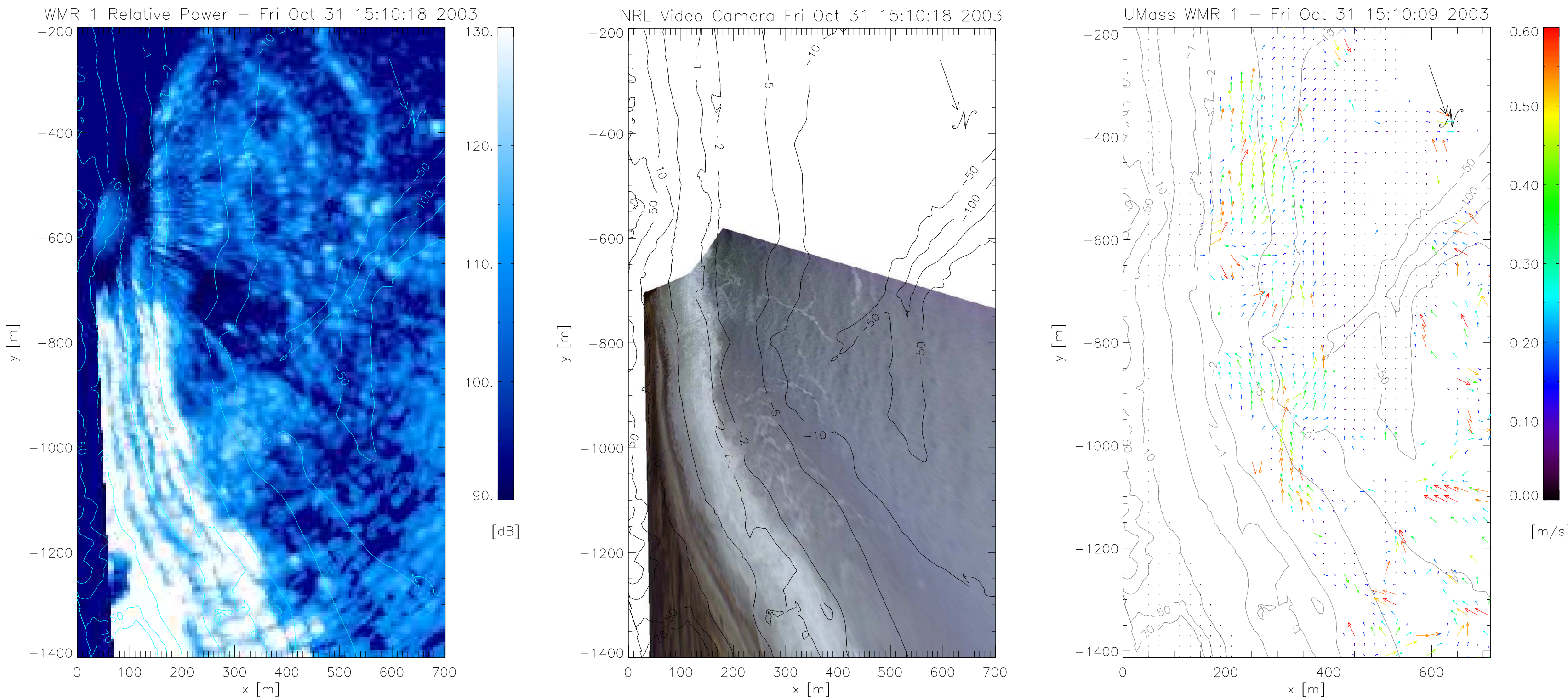


Figure 3: (a) Contour plot of joint histograms of NRCS and Doppler velocity for the time series shown in Figure 7 (x=76.6 m, y=52.3 m). The NRCS bin size is 2 dB and the Doppler velocity bin size is 0.2 m/s. (b) Radar Doppler velocity versus ADV radial velocity. Doppler velocities were selected from pixels with NRCS value between -40 dB and -25 dB. The solid line shows the least squares fit for the data, and the dotted line is a one to one relationship with an 0.81 m/s offset.



(a) Radar (b) Video (c) Surface Velocity

Figure 4: (a) Radar backscatter image, (b) video image, and (c) retrieved surface velocities from radar backscatter data collected on 31 Oct 2003 at 15:10:18 UTC. The vector field is computed from radar image sequences. Vectors within the surf zone are omitted due to contamination by bore phase velocities. Note apparent rip current signature at coordinates -1000¡y¡800.

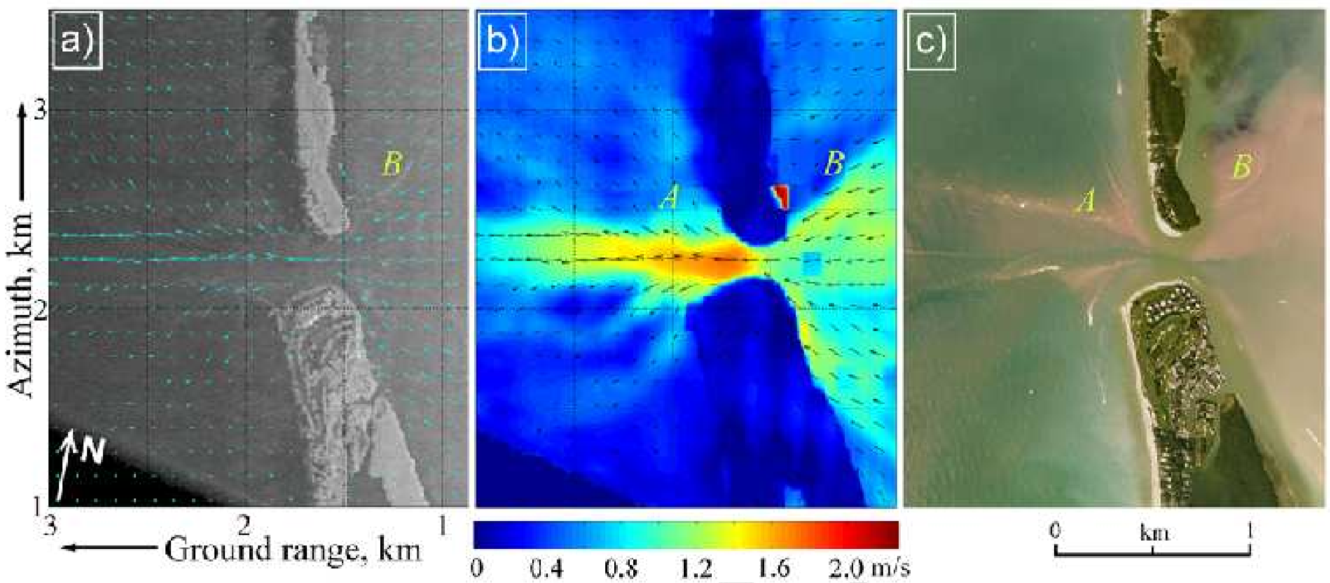


Figure 5: DBI SAR magnitude image (a), velocity image (b), and aerial photo (c) of Redfish Pass inlet near Ft. Myers, FL. Retrieved surface velocity vectors are overlaid on radar images which were obtained near maximum ebb tidal flow. Note, aerial photo is not coincident in time with radar imagery.